

10 January 2003

TO: Rick Marks
David Fulla
Trawler Survival Fund
Associated Fisheries of Maine

FROM: Paul Starr
Fisheries Scientist

RE: Analysis of NFMS Trawl Survey Data: R/V Albatross IV & F/V Sea Breeze

Introduction

You engaged me on 07 January 2003 to do some analyses on data from an experimental trawl survey undertaken by the above two vessels between 28 October – 06 November 2002 in waters off the east coast of Cape Cod, Massachusetts. This survey was designed to test whether a specific “worse case” net configuration fished differently than an ideal or “optimal” net configuration. A short description of the design of the experiment is available on a Northeast Fisheries Science Centre (NEFSC) website (http://www.nefsc.noaa.gov/survey_gear/data/), which also provides links to EXCEL files containing some of the data from these cruises and to a cruise report (AL 02-11 Trawl Study) which describes in greater detail the experimental design.

Design

The important points of the experimental design (as I understand them) are:

1. There are two net configurations: one is meant to represent an ideal configuration (OPT) which would be preferred in a trawl survey situation, the other is meant to mimic a deteriorated or sub-optimal configuration (WCS) which had evolved over a period of time in some of the research surveys in these waters.
2. Three area strata were selected, each of the same size (85.9 km² or 25 nm²). These areas represented different depth ranges, with the areas having mean depths of 87, 139 and 198 m. Therefore, the area strata also represent depth strata.
3. Stations were randomly selected within each area by sub-dividing the area into 100 sub-blocks (approximately 927X927 m) and selecting 16 of these sub-blocks randomly for each day of fishing. The design is not specific about how a station was selected within a sub-block.
4. Each area was fished twice by the R/V Albatross IV, once with the OPT configuration and the other with the WCS configuration. The sequential order that each net configuration was fished in an area was determined by a coin toss. Each net configuration was fished for one full day before switching to the other net configuration.
5. A second vessel, F/V Sea Breeze, fished alongside of the Albatross IV and an attempt was made to match the tows made by the research vessel. This vessel did not match every tow by the Albatross IV because it was only single crewed.

Data

Data were provided to me in several files, some of which were downloaded from the above website and others were sent to me specifically after a request. The files were:

File name	Data contained	Source
ALBtrawldata.xls	Catch data for the Albatross IV and basic information for each tow	NEFCS website
SBtrawldata.xls	Catch data for the Sea Breeze and basic information for each tow	NEFCS website
Marks-A4 stationdat.xls	More detailed station data for the Albatross IV, including tow speed, tow depth and tow duration information	Sent to me by NEFCS
AL0211-distance.xls	Doorspread, wingspread, and headline heights for the Albatross IV & Sea Breeze. Also calculated tow distance from latitudes and longitudes	Sent to me by NEFCS

In addition, Frank Almeida (NEFCS) provided me with the following interpretative information which I used in this analysis:

1. The Sea Breeze doorspread was 60.4 m (average of 58.5-62.2 m [32-34 fm] for tows 1-18) when the groundrope was 54.9 m [30 fm]. The Sea Breeze doorspread was 76.8 m (average of 73.3-80.5 m [40-44 fm] for tows 19-61) when the groundrope was 91.5 m [50 fm].
2. An average speed of 5.56 km/h [3.0 nm/h] was used for the missing cell for Sea Breeze tow 50 which had no vessel speed data (same as the values for tows 49 and 51).
3. The tow end time for Sea Breeze tow 52 was reduced by 1 hour due to a data entry error. The start and end times for Sea Breeze tow 31 were reversed.
4. Missing doorspread values for the Albatross IV (12 of the 72 tows were missing this value) were filled in by using the mean value for the appropriate area/gear combination.

The tow duration for Albatross IV tow 12 was 24.4 minutes if the beginning and end times were subtracted but were listed as 30.4 minutes in the file. I used 24.4 minutes in my calculations below.

Preliminary investigations of the data

The data set I compiled had the correct number of tows assigned to the relevant area and gear strata (Table 1). I was not able to match the Sea Breeze with the appropriate Albatross IV tows because there was no linking code in the files which I received and I did not have the time to do a manual link.

Table 1. Distribution of tows by area and gear type for the Albatross IV and by area for the Sea Breeze for the survey conducted in three areas off Cape Cod, Massachusetts, 28 October – 06 November, 2002.

Vessel	“Optimal” Net Configuration				“Worst Case Scenario” Net Configuration				Combined Tows			
Area	1	2	3	Total	1	2	3	Total	1	2	3	Total
Albatross IV	10	13	13	36	10	13	13	36	20	26	26	72
Sea Breeze	–	–	–	–	–	–	–	–	17	24	20	61

Three estimates of the distance travelled for the Albatross IV were provided and unfortunately they were all different. The sources for each estimate are listed in Table 2 below. I was informed by NECFS that the TowDistance field (Method 1; Table 2) is the integral of the GPS positions from the plotting software which are updated every 10 seconds. Therefore, this is clearly the preferred field to use for this measurement. Unfortunately, there is no equivalent measure of tow distance for the Sea Breeze. All measures of distance towed have been plotted for each vessel in Figure 1.

Table 2. Available distance travelled fields for the Albatross IV and the Sea Breeze.

Method	Field	Source	Units
1	TowDistance (integral) [Albatross IV only]	Provided in file "Marks-A4 stationdat.xls" sent 08 Jan. 03	nm (as stated on page 7 of <i>SVDBSvariabledefinitions.pdf</i>)
2	TowDistance (interpolation) [both vessels]	Calculated by interpolation from beginning and end latitude and longitude points in file "AL0211-distance.xls" sent 08 Jan. 03	nm (mi indicated on column header which I have assumed are actually nm as the calculations are based on latitudes and longitudes)
3	TowDistance (speed*duration) [both vessels]	As a check, I have multiplied the speed by towduration (=TimeEnd-TimeBeg) to get tow distance	nm, the units for DESSPEED are not provided in <i>SVDBSvariabledefinitions.pdf</i> , but I was told nm/h by NECFS. The file <i>Sbvariabledefinitions.pdf</i> indicates this is nm/h for the Sea Breeze

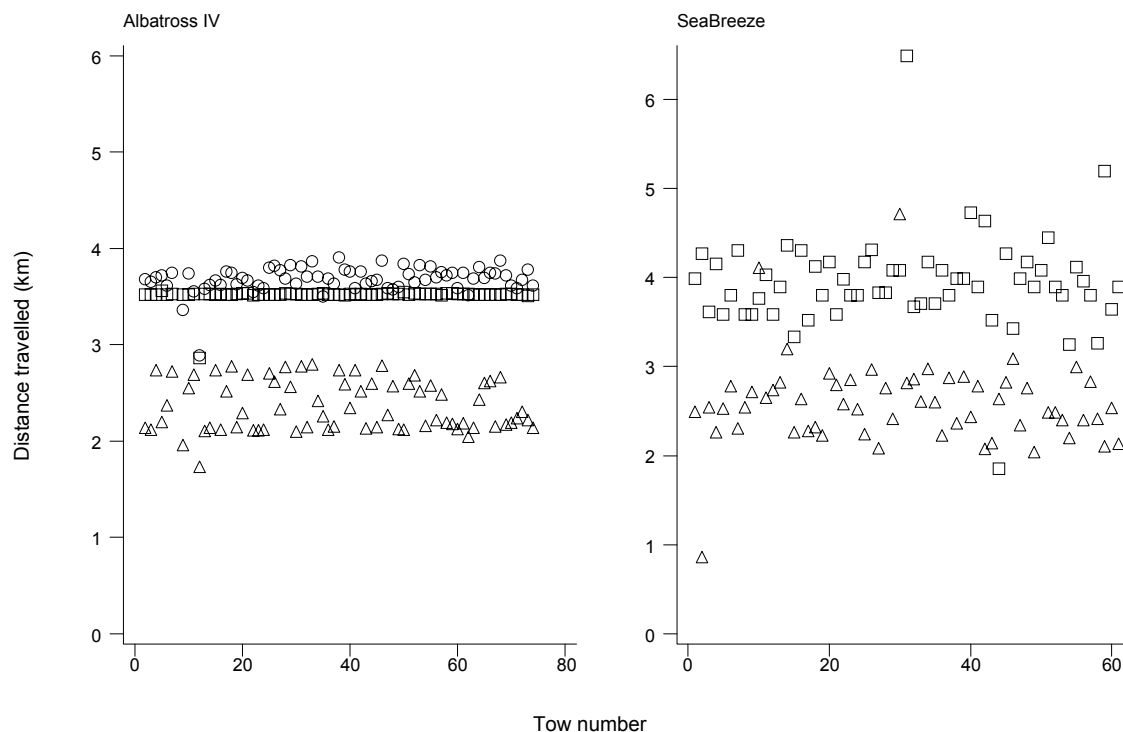


Figure 1. Plot of distance travelled for each tow of the Albatross IV [left panel] and the Sea Breeze [right panel] based on three sources of available estimates (Table 2). All values have been converted to kilometres based on the unit assumptions provided in Table 2. Plotting symbols are: triangle, interpolated from latitude and longitude; square, estimated by [speed*tow_duration]; circle, tow_distance field (Albatross IV only).

The distance travelled is much lower (Table 3; Figure 1) when calculated using the interpolation method (Method 2; Table 2) than for the other methods, so this is clearly not a desirable field to use if one assumes that Method 1 represents the correct quantity. Method 3 (speed*duration) is reasonably close to Method 1 for the Albatross IV. For calculating biomass levels in the comparison between the gear configurations, I used the integral method (Method 1; Table 2). However, when comparing biomass estimates between the two vessels, I used the [speed*duration] method (Method 3; Table 2) as this would be the most comparable method between the two vessels and less biased than the interpolation method. Note that the CV (Coefficient of variation=standard deviation/mean) for the mean distance travelled is more variable for the Sea Breeze than for the Albatross IV (Table 3; Figure 1) as there was much more variation in the time towed for this vessel. It is interesting to note that the variability in distance towed rises for the Albatross IV when based on the interpolation method (Method 2; Table 2) which may be another reason to avoid using this method. The mean distance travelled is slightly greater for the Sea Breeze than for the Albatross IV (Table 3).

Table 3. Mean and CV of the distance travelled by vessel (in km and %) for each of the available data fields for both vessels (Table 2). –, not available

Vessel	TowDistance (integral)	Tow Distance (interpolation)	Tow Distance (speed*duration)
Mean			
Albatross IV	3.68	2.37	3.52
Sea Breeze	–	2.59	3.94
CV			
Albatross IV	4%	11%	2%
Sea Breeze		19%	14%

More difficult to interpret is the disparity observed in the doorspread estimates between the two vessels (Table 4) because it implies that the fishing power of the Sea Breeze is about 3 times higher than the Albatross IV. Any comparison of biomass estimates between the two vessels will necessarily reflect the ratio of the two doorspreads, with the relative CPUE of the Sea Breeze being scaled down by that ratio.

Table 4. Mean estimate of doorspread (m) by area for each vessel.

Vessel	Area			Total
	1	2	3	
Albatross IV	24.77	24.45	23.77	24.29
Sea Breeze	60.35	76.12	76.81	71.95

Catch data in kilograms for twenty species (and the total catch) were extracted from the original data set for each vessel. This set of species was selected by choosing the top 20 species by weight caught by the Sea Breeze, excluding invertebrate and pelagic species. After some consultation with Rick Marks, Atlantic herring and loligo squid were added back into the list.

Table 5. Species list for the analysis presented as total catch by area and vessel.

Species	Albatross IV				Sea Breeze			
	Area			Total	Area			Total
	1	2	3		1	2	3	
Total catch	10,522.2	7,109.5	2,316.8	19,948.5	31,847.7	27,823.2	14,125.0	73,795.9
Haddock	7,251.8	9.8	0.0	7,261.6	20,710.9	21.8	0.0	20,732.7
Silver Hake	186.9	1,705.3	60.4	1,952.6	498.8	11,597.4	323.6	12,419.8
Atlantic Herring	52.7	3,098.1	3.7	3,154.5	109.2	7,256.3	12.7	7,378.2
Redfish	1,723.0	92.9	0.4	1,816.3	4,811.2	321.8	0.0	5,133.0
Little Skate	0.0	0.0	225.0	225.0	0.0	0.0	4,631.6	4,631.6
Spiny Dogfish	5.4	676.9	12.1	694.4	43.6	3,813.3	37.6	3,894.5
Red Hake	98.8	527.3	272.1	898.2	312.9	1,257.0	1,488.8	3,058.7
Goosefish	14.0	53.0	77.4	144.4	384.6	713.9	1,652.5	2,751.0
White Hake	98.1	529.8	16.2	644.2	393.5	1,350.4	31.0	1,774.9
Cod	413.4	3.7	10.7	427.8	1,717.7	24.5	6.7	1,748.9
Barndoor Skate	0.0	1.4	142.2	143.6	3.2	32.0	1,513.4	1,548.6
Winter Skate	0.0	1.9	122.3	124.2	32.3	3.7	1,253.4	1,289.4
Witch Flounder	32.3	23.5	4.6	60.4	424.1	391.4	118.8	934.3
Pollock	244.5	8.4	0.2	253.0	795.8	26.4	1.5	823.7
Smooth Skate	56.7	4.5	0.0	61.2	660.8	103.7	23.6	788.1
Winter Flounder	0.0	0.0	152.2	152.2	1.6	0.0	782.2	783.8
Thorny Skate	141.6	1.6	2.1	145.3	569.1	55.8	69.0	693.9
American plaice	9.3	157.9	1.4	168.6	25.9	603.4	0.4	629.7
Loligo	1.1	1.0	385.6	387.7	5.8	0.4	492.6	498.8
Fourspot Flounder	0.0	0.3	183.1	183.4	0.0	0.0	359.1	359.1

Analytical method

I decided that the best way to analyse these data was to apply the standard procedure used to estimate biomass from a random stratified trawl survey. This procedure also provides an estimate of the variability of the mean biomass index, allowing for a direct comparison of the estimates between treatments or vessels. Such procedures are well known in the fisheries science community and the properties of the estimators are well understood (Quinn & Deriso 1999).

Subscripts for species have been dropped in the following equations and a single subscript (i) is used to indicate the stratum. A stratum in this analysis is either an area/gear configuration combination (for the Albatross IV treatment comparison) or an area/vessel combination (for the comparison between the Albatross IV and the Sea Breeze). The initial step in the analysis calculates a CPUE ($C_{i,t}$) for each tow. As this is a swept area biomass estimate, the CPUE (in kg/km²) is defined as:

$$C_{i,t} = \frac{W_{i,t}}{(D_{i,t} * H_{i,t})} \quad \text{Eq. 1}$$

where $W_{i,t}$ is the catch in kg, $D_{i,t}$ is the distance towed, and $H_{i,t}$ is the width of the net (the doorspread field was used in this analysis as a relative measure of the width of the net) and t is the tow index. As the three areas were equal in size, I assumed that the stratum area was equal to 1.0 km² in the calculation of the mean biomass (B is in kg so the dummy area term is needed to ensure that the biomass units are correct):

$$B = \sum_i \frac{\sum_t C_{i,t} A_t}{n_i} \quad \text{Eq. 2}$$

where n_i is the number of tows in stratum i .

The variance of the survey biomass estimate V is calculated in kg^2 as follows:

$$V = \sum_i \frac{Z_i A_i^2}{n_i} \quad \text{Eq. 3}$$

where Z_i = variance of CPUE ($C_{i,t}$ in kg^2/km^4) in stratum i .

The precision of the survey is often expressed in terms of the coefficient of variation (CV) which is approximated from the values obtained in Eq. 2 and Eq. 3:

$$CV = \frac{\sqrt{V}}{B} \quad \text{Eq. 4}$$

Results: gear configuration trials

The biomass estimates for the 20 selected species and for the total catch are reasonably comparable for most species, with a few notable exceptions including haddock and herring (Table 6; Figure 2). The overall estimate of biomass is greater for the “worst case scenario” because there are considerable differences in the haddock and Atlantic herring biomass estimates between the two gear configurations which are species which have high catch rates. However, the number of species which have larger biomass estimates is similar between the two net configurations, with 12 species having greater abundance using the optimal configuration and 9 species (including the total catch) having greater abundance when using the “worst case” configuration.

The CVs appear to be generally lower when estimated from the optimal net configuration, with 15 of the 21 CVs being lower (Table 6; Figure 3). There are some exceptions to this. For instance, both pollock and haddock have much higher CVs using the optimal configuration. But it may be that the most important effect of the optimal net configuration is to reduce the variation between catch rates rather than affecting the mean catch rate.

Table 6. Biomass and CV estimates by species and for total catch for two net configurations tested on the Albatross IV. The configurations are OPT: optimal net configuration; WCS: worst case scenario net configuration. Also shown are the three letter codes used as plotting symbols in Figure 2 and Figure 3.

Species	Code	Biomass (kg)		CV (%)	
		OPT	WCS	OPT	WCS
Total	TTL	8,547	11,422	25	17
Haddock	HAD	3,372	4,812	53	30
Silver Hake	SHK	782	945	10	18
Atlantic Herring	AHR	507	2,230	26	42

Species	Code	Biomass (kg)		CV (%)	
		OPT	WCS	OPT	WCS
Redfish	RDF	1,030	980	34	30
Little Skate	LSK	94	99	23	22
Spiny Dogfish	SDG	116	477	37	43
Red Hake	RHK	396	404	8	11
Goosefish	GOF	79	49	18	32
White Hake	WHK	355	212	12	18
Cod	COD	271	209	35	26
Barndoor Skate	BSK	57	67	34	37
Winter Skate	WSK	9	99	45	48
Witch Flounder	WFL	27	34	23	29
Pollock	POL	162	124	62	34
Smooth Skate	SSK	44	23	29	33
Winter Flounder	WFL	59	75	17	21
Thorny Skate	TSK	82	82	32	39
American plaice	AMP	89	56	13	18
Loligo	LOL	274	62	25	27
Fourspot Flounder	FFL	76	87	17	19

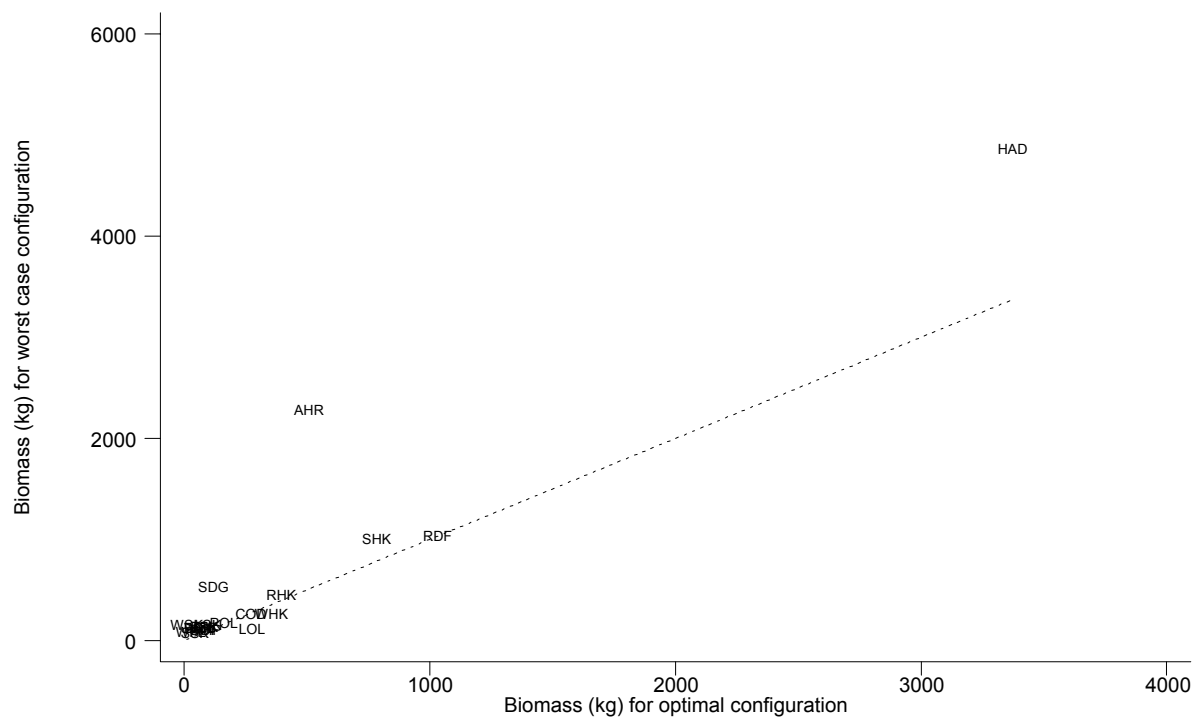


Figure 2. Comparison of mean biomass indices obtained for the two net configurations employed on the Albatross IV. Plotting symbols use a three-letter code for each species (provided in Table 6). Total catch comparison has not been plotted. Dashed line is 1:1.

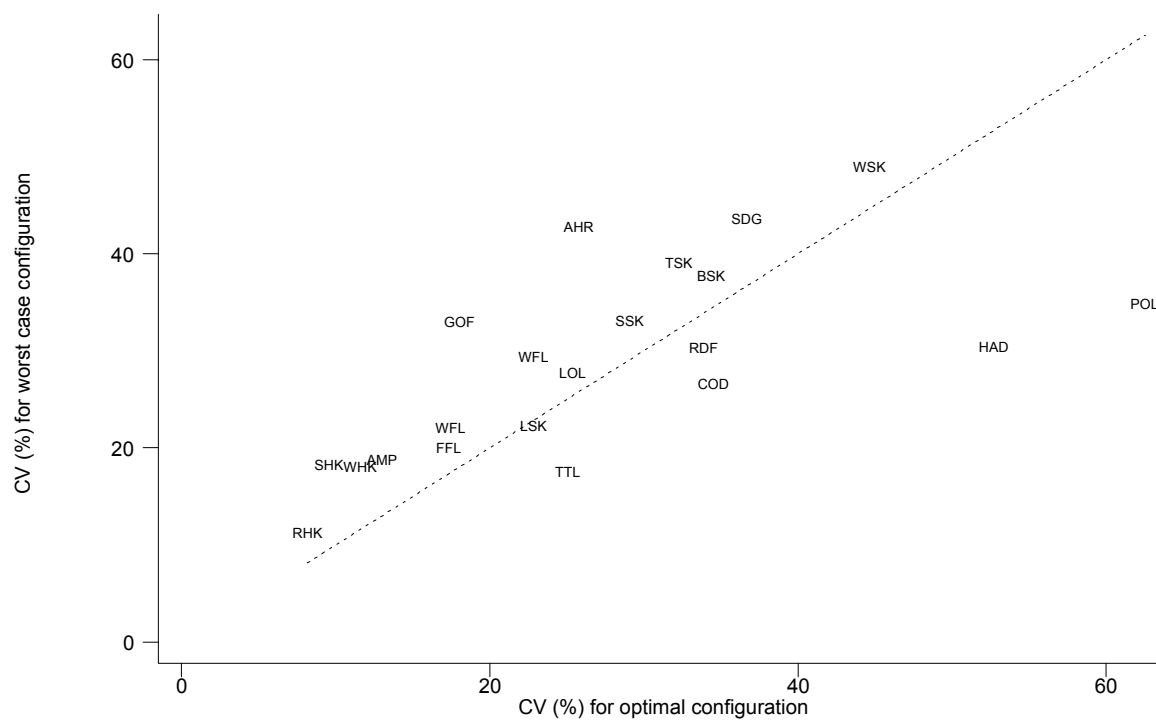


Figure 3. Comparison of estimated CV (%) obtained for the two net configurations employed on the Albatross IV. Plotting symbols use a three-letter code for each species (provided in Table 6). Dashed line is 1:1.

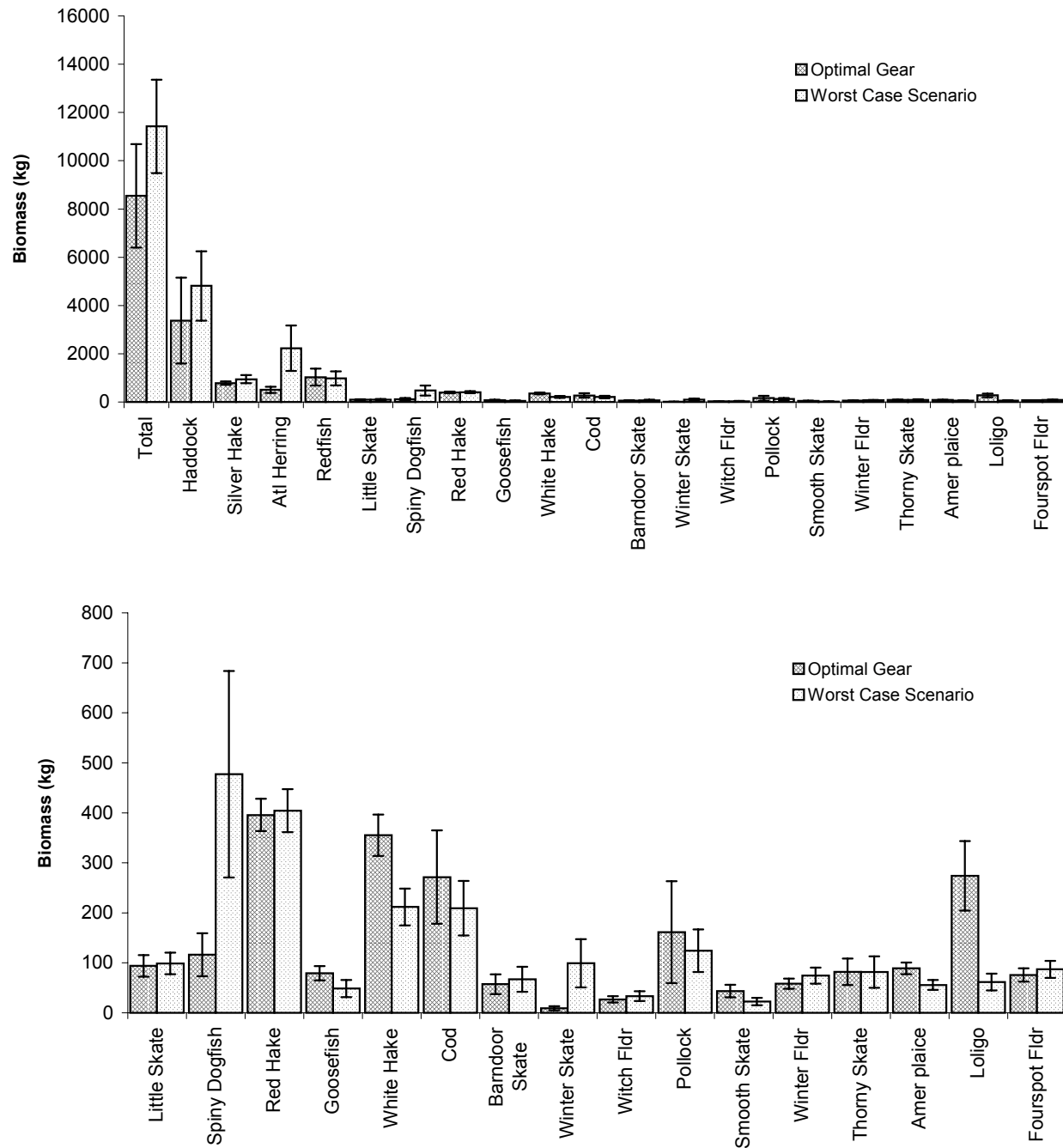


Figure 4. Bar plots of the estimated biomass (in kg) by species and for total catch using the two gear configurations on the Albatross IV. Plotted error bars are ± 1 standard error. [top panel] all species plotted including total catch. [lower panel] plot with the species with the 5 largest catches excluded for scaling purposes.

Significance tests on these data are difficult to perform due to the requirement of making distributional assumptions which may not be correct. However, bar plots with one standard error added and subtracted from the mean biomass estimate show clear overlaps in 16 of the 21 species/total combinations (Figure 4) which indicate that there is little statistical difference

between these two net configurations for most species. Extending the comparison to two standard errors eliminated all the remaining species except for loligo squid. This result is not surprising as it is likely that there should be at least one “significant” test in a group of 20 or more comparisons.

This analysis implies that there is likely to be no detectable difference between the two gear types as tested in this experimental design or that the data have insufficient power to discriminate between these two configurations. As a quick check on this result, a simple ANOVA was performed on the Albatross IV data by assuming that gear, area and species were “treatments” (Table 7). This analysis also shows that gear is not a significant treatment, while area and species are highly significant. This analysis was repeated with an area*species interaction term (Table 8) which is also a significant factor, but gear remains non-significant.

Table 7. Results of simple ANOVA using the CPUE variable from the Albatross IV data, assuming that gear, area and species are treatments.

		Number of obs = 1512		R-squared = 0.2703	
		Root MSE = 1170.49		Adj R-squared = 0.2591	
Source	Partial SS	df	MS	F	Prob > F
Model	755330340	23	32840449.5	23.97	0.0000
area	53916221.9	2	26958111.0	19.68	0.0000
gear	3371305.50	1	3371305.50	2.46	0.1169
species	698042812	20	34902140.6	25.48	0.0000
Residual	2.0386e+09	1488	1370050.46		
Total	2.7940e+09	1511	1849083.67		

Table 8. Repeat of the simple ANOVA using the CPUE variable from the Albatross IV data performed in Table 7 with an additional term describing the interaction of area*species.

		Number of obs = 1512		R-squared = 0.4545	
		Root MSE = 1025.90		Adj R-squared = 0.4308	
Source	Partial SS	df	MS	F	Prob > F
Model	1.2700e+09	63	20158615.4	19.15	0.0000
area	53916221.9	2	26958111.0	25.61	0.0000
gear	3371305.50	1	3371305.50	3.20	0.0737
species	807251125	20	40362556.2	38.35	0.0000
area*species	514662429	40	12866560.7	12.23	0.0000
Residual	1.5240e+09	1448	1052467.30		
Total	2.7940e+09	1511	1849083.67		

Results: comparison between vessels

There appears to be greater differences between the Albatross IV and the Sea Breeze compared to the differences observed between the two gear types (Table 9). However, the differences are still not very large and it is not clear how important they are. In general, the Sea Breeze appears to estimate larger biomass levels than the Albatross IV (Table 9; Figure 5), with 17 of the 21 species indices being greater when estimated from the Sea Breeze data. The CVs are also lower when calculated from the Sea Breeze data than when using the Albatross IV data, with 16 of 21 species having lower CVs for that vessel (Table 9; Figure 6).

Bar plots with one standard error added and subtracted from the mean biomass estimate show less overlap than for the gear configuration comparison, with 13 of the 21 species/total combinations having no overlap at this level (Figure 7) and for only one of these comparisons is the biomass index larger for the Albatross IV. Seven of these species still do not overlap when the comparison is extended to two standard errors, all of which have larger biomass indices from the Sea Breeze data. This comparison indicates that there is likely to be a difference in the fishing power of these two vessels, with the Sea Breeze estimating consistently larger biomass levels. The greater level of significance of these comparisons compared to the comparisons between the two gear configurations is partially due to the larger number of tows available to make this second set of comparisons. There were only 36 tows available for the first comparison and 72 and 61 tows available for the second comparison (Table 1).

Table 9. Biomass and CV estimates by species and for total catch for the Albatross IV and the Sea Breeze. All Albatross IV tows were combined, regardless of the gear configuration used.

Species	Biomass (kg)		CV (%)	
	Albatross IV	Sea Breeze	Albatross IV	Sea Breeze
Total	10,435	14,433	14	12
Haddock	4,255	5,237	28	24
Silver Hake	911	1,766	11	13
Atlantic Herring	1,452	1,059	37	27
Redfish	1,038	1,243	22	29
Little Skate	101	830	15	9
Spiny Dogfish	309	586	37	44
Red Hake	419	508	7	6
Goosefish	67	482	17	8
White Hake	298	293	11	11
Cod	249	440	22	21
Barndoor Skate	66	278	25	14
Winter Skate	57	247	47	58
Witch Flounder	31	178	18	11
Pollock	149	207	37	33
Smooth Skate	34	188	22	11
Winter Flounder	70	136	14	12
Thorny Skate	85	169	24	16
American plaice	76	88	12	9
Loligo	177	86	24	24
Fourspot Flounder	86	65	13	13

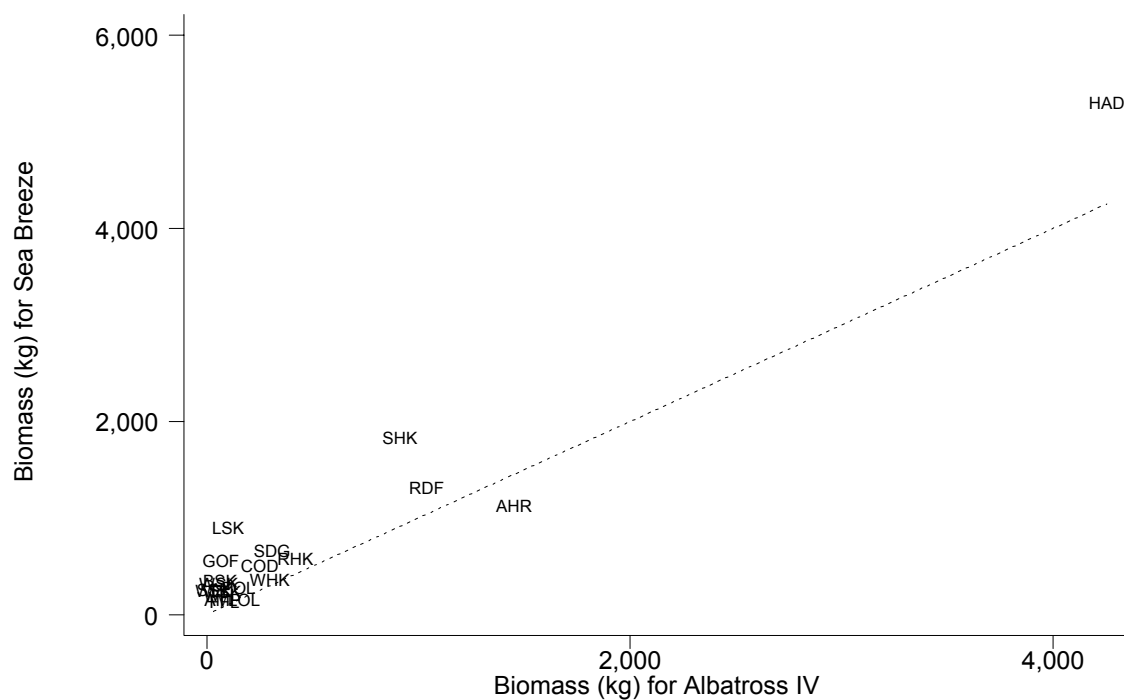


Figure 5. Comparison of mean biomass indices obtained for the Albatross IV and the Sea Breeze. All Albatross IV tows were combined, regardless of the gear configuration used. Plotting symbols use a three-letter code for each species (provided in Table 6). Total catch comparison has not been plotted. Dashed line is 1:1.

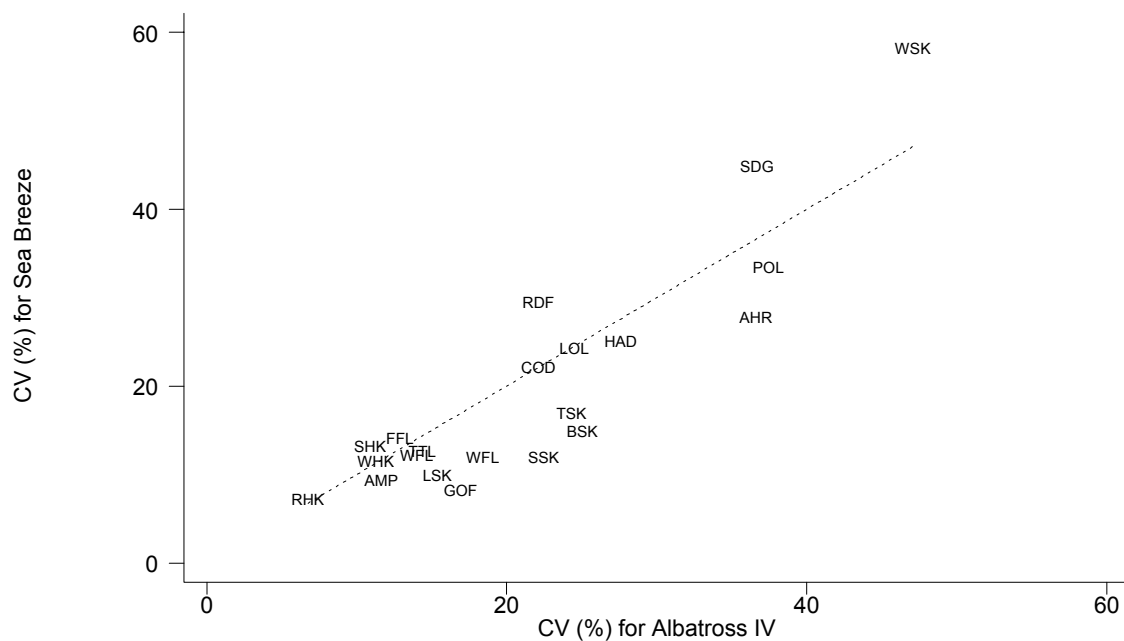


Figure 6. Comparison of estimated CV (%) obtained for the Albatross IV and the Sea Breeze. All Albatross IV tows were combined, regardless of the gear configuration used. Plotting symbols use a three-letter code for each species (provided in Table 6). Dashed line is 1:1.

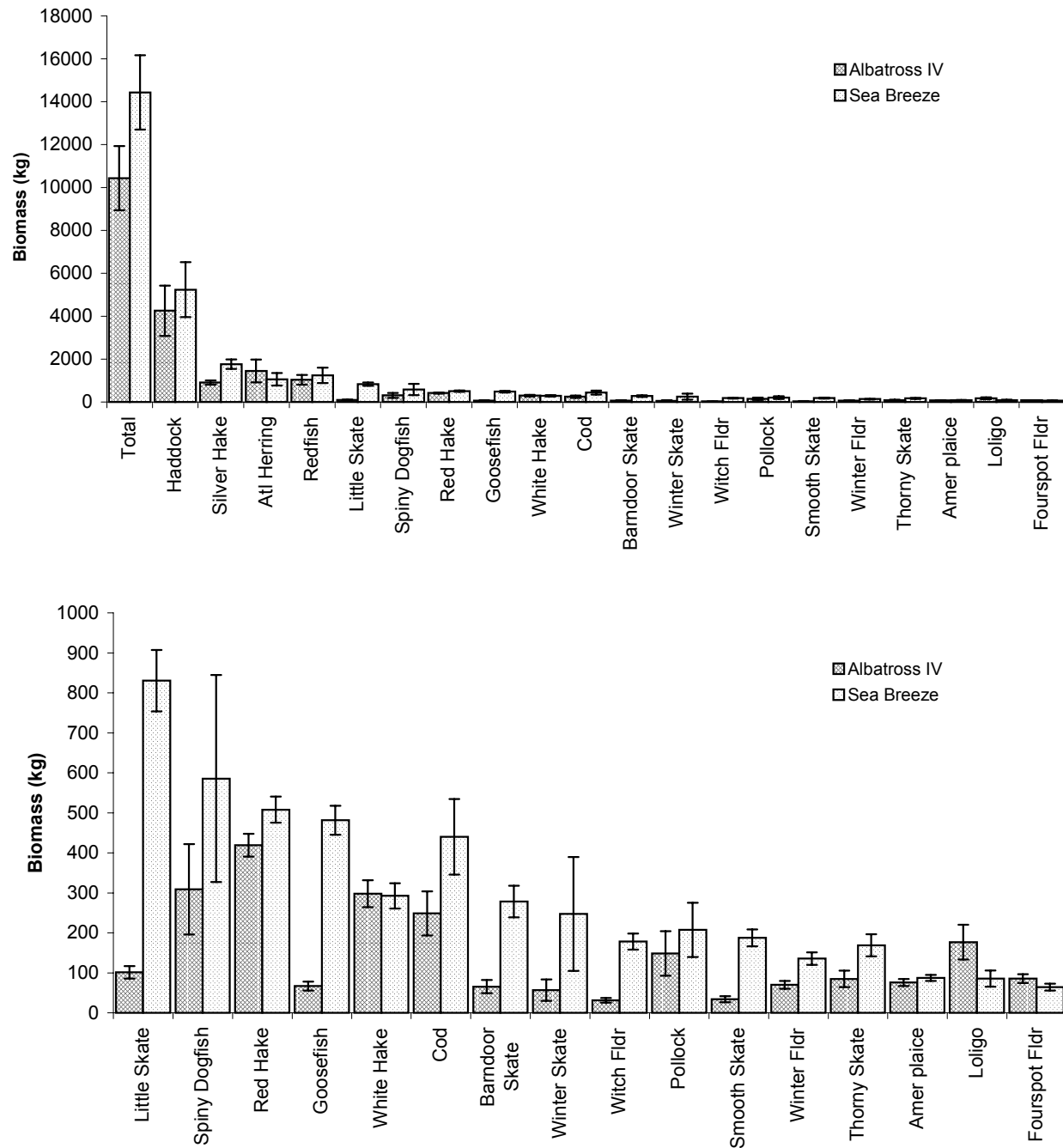


Figure 7. Bar plots of the estimated biomass (in kg) by species and for total catch the Albatross IV and the Sea Breeze. All Albatross IV tows were combined, regardless of the gear configuration used. Plotted error bars are ± 1 standard error. [top panel] all species plotted including total catch. [lower panel] plot with the species with the 5 largest catches excluded for scaling purposes.

The simple ANOVA was repeated for these data as well, using vessel, area and species as treatments (Table 10). All three treatments are significant, with vessel have the least explanatory power. All three possible interaction terms were offered to the model in the second ANOVA (Table 11) as they all make some logical sense. Fortunately, the interaction term between vessel

and area is not significant. The species*area interaction term is highly significant as in the Albatross IV gear configuration model (Table 8) and, while the vessel*species term is significant, it also has low explanatory power.

Table 10. Results of simple ANOVA using the CPUE variable from the Albatross IV and Sea Breeze data, assuming that vessel, area and species are treatments.

		Number of obs = 2793		R-squared = 0.3180	
		Root MSE = 1265.95		Adj R-squared = 0.3124	
Source	Partial SS	df	MS	F	Prob > F
Model	2.0694e+09	23	89973306.2	56.14	0.0000
area	114391326	2	57195663.0	35.69	0.0000
vessel	10633264.6	1	10633264.6	6.63	0.0101
species	1.9432e+09	20	97161925.9	60.63	0.0000
Residual	4.4377e+09	2769	1602636.87		
Total	6.5071e+09	2792	2330618.74		

Table 11. Repeat of the simple ANOVA using the CPUE variable from the Albatross IV and Sea Breeze data performed in Table 10 with an additional terms describing the interactions of area*species, vessel*species, and vessel*area.

		Number of obs = 2793		R-squared = 0.5105	
		Root MSE = 1084.72		Adj R-squared = 0.4951	
Source	Partial SS	df	MS	F	Prob > F
Model	3.3220e+09	85	39082071.6	33.22	0.0000
area	113930199	2	56965099.5	48.41	0.0000
vessel	11411979.6	1	11411979.6	9.70	0.0019
species	2.2227e+09	20	111135496	94.45	0.0000
species*area	1.1931e+09	40	29826366.5	25.35	0.0000
species*vessel	53267598.4	20	2663379.92	2.26	0.0011
vessel*area	1535778.80	2	767889.40	0.65	0.5208
Residual	3.1851e+09	2707	1176620.41		
Total	6.5071e+09	2792	2330618.74		

Discussion

This analysis was performed in a relatively short period of time using unfamiliar data in an unfamiliar fishing situation. Therefore, it is possible that some of these analyses may have misunderstood some aspect of the experimental design or how the vessels operated while performing the survey. It is also possible that the data have been wrongly interpreted.

Quite a bit of time was spent on assembling the data and checking for potential errors. This step is required because errors at this stage could easily invalidate an entire analysis. I have tried

to document all the issues I encountered with the data and the corrections that I made in first section of this report. This was done so that the analyses can be repeated.

The main result from this analysis is that the available data cannot distinguish between the two tested net configurations. This lack of a conclusive result is never satisfying but is a frequent occurrence in fisheries situations where the underlying variability in catch rates for any species is always very large, causing the statistical tests to have low power. The CVs listed in Table 6 are generally quite big, with only 7 and 6 species (for OPT and WCS respectively) below the 20% CV threshold. Note that a 20% CV implies that a paired comparison needs to differ by about 50% in order to provide a statistically significant result at a 95% level. This would explain why so few of the species comparisons provided in Figure 4 are significantly different.

I should note that there is some indication in the analysis that the CVs from using the “optimal” net configuration are generally lower than when using the “worse case” net configuration, with 15 of the 21 species having lower CVs for the “optimal” configuration (Figure 3). However, this level of difference is not significant when a simple Wilcoxon sign-rank test is applied ($p=0.26$). But it is possible that one of the benefits of using an “optimal” net configuration rather than a sub-optimal configuration is that the variability in the biomass estimates is reduced.

The comparison between the Albatross IV and Sea Breeze is more conclusive, with reasonable evidence that there is a real difference in the catch rates between these vessels. This difference is apparent in spite of the widely disparate estimates of doorspread for these two vessels which are presented in Table 4. This comparison also gives some reason to believe that the statistical tests employed here have the capacity to determine differences if they exist in the data.

I note that the CVs obtained by the Sea Breeze are lower than those from the Albatross IV in 16 of the 21 species investigated (Figure 6). This is in spite of the fact that the Albatross IV did 11 more tows than performed by the Sea Breeze and that the Albatross IV tow distances show very little variation compared to the equivalent Sea Breeze values (Table 3; Figure 1). A simple Wilcoxon sign-rank test is significant in this instance ($p=0.04$). My suspicion is that this difference is due to a “skipper effect” with the vessel master on the commercial vessel better able to obtain more uniform results. More information about how the stations were selected within each randomly selected sub-block would be needed to understand how much latitude each vessel master had in selecting the track line.

We could also ask whether a larger experiment involving more sample tows would have had more power to determine if there is a difference between the two net configurations. Note that the results from the vessel comparison show that overall variability drops with additional tows. Only seven and six species have CVs that are less than 20% for the two gear configurations (Table 6) which are based on 36 tows each while 10 and 13 species (for the Albatross IV and Sea Breeze respectively; Table 9) have CVs that are less than 20% for the vessel comparison which are based on 72 and 61 tows for the two vessels. However, the present analysis leads to the conclusion that the additional variability introduced by the two net configurations is probably low compared to the high variability in catch rates. Therefore, my inclination would be to apply available resources towards reducing the variability in existing surveys and consideration of designing new and more representative surveys.

I have been asked to make recommendations on:

- a series of analyses which could rigorously test the difference between the two gear configurations;
- the sample sizes required to demonstrate differences in fishing power between the two gear configurations, given specified levels of the difference;
- additional field work that could be done to test the differences in fishing power.

While all of these recommendations would be valid and useful to address, they would involve several days of additional work and time is presently at a premium. Therefore, I cannot attempt to address these issues at this time.

Finally, I should mention that I have been involved in designing a large multi-species demersal groundfish trawl survey for these past few months with a number of colleagues at the Pacific Biological Station in Nanaimo, British Columbia, Canada. The objective is to design a coastwide survey between the depths of 50 to 500 m that will obtain a CV of 20% or less for as many species/stocks as possible while still keeping the size of the survey manageable. In the course of this design process, we have discovered that there many compromises required in the survey design as soon as multiple objectives are specified. Trying to get the best CV for as many species as possible means that no one species will be as well covered as it would be if the survey were targeted at a particular species. It is likely that this design compromise is also affecting the analyses in this paper and is partly the reason that the power to discriminate between the two gear configurations is low.

Reference:

Quinn, T.R. and R.B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press. 542 p.